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In pursuit of excellence: a historical investigation of scientific production in Indonesia's higher education system, 1990–2020

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Abstract
In its pursuit of global university rankings, Indonesia introduced a series of higher education policies, one in 2014 to grant autonomy to a select group of universities, and another in 2017 to tie financial and promotional incentives to scientific publications for all researchers. To examine scientific productivity surrounding these policies, we use bibliometric data from Scopus spanning three decades from 1990 to 2020. We investigate the patterns of publication and collaboration and analyze them across journal quartiles, academic fields, and researcher cohorts. Our findings reveal that publications increased dramatically for both autonomous and non-autonomous higher education institutions after 2014. Single-university authorship was common practice and skewed publication quality towards Q3 and Q4 journals, while co-authorships with foreign organizations pulled the shift towards Q1 journals consistently across all fields. New researchers starting in 2014 published fewer Q1 and more Q3 and Q4 publications than the earlier cohort. We highlight policy implications on the need for a balance between publication quantity and quality and call on Indonesian policymakers to introduce holistic higher education reforms rather than introducing reforms that focus on the performance of the university for ranking purposes.

Keywords Indonesian higher education · Scientific productivity · Research incentives · Bibliometric analysis · Scientific quality

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Introduction

In the global knowledge economy, higher education institutions (HEIs) have been recognized as key producers of knowledge and drivers of innovation (Altbach et al., 2010; Salmi, 2016). At the same time, they have been subjected to various pressures like internationalization and the marketization of higher education, which have inevitably created an increasingly competitive environment that has transformed the way HEIs are governed. Key to this global competition, mainly characterized by the pursuit for excellence through global university rankings and world-class status (Zhang et al., 2016), is various mechanisms to raise scientific production, like financial and promotional incentives aimed at motivating productivity (Salmi, 2016; Sandy & Shen, 2018). Coupled with the advent of performative accountability (Oancea, 2008), metrics and other indicators to regulate responses to the competition have emerged, thereby validating the neo-institutional idea (DiMaggio & Powell, 1991) that only by conforming would HEIs obtain the legitimation that has continuously defined the global landscape of higher education.

Although the pursuit for university rankings and world-class status has been met with ongoing criticisms (Gonzales & Núñez, 2021), they have been utilized as key drivers of higher education governance reforms (Marques & Powell, 2020; Sukoco et al., 2021). In addition to increased autonomy and greater calls for accountability, national governments are now increasingly relying on university rankings and the pursuit for world-class status to allocate public funds to HEIs. In return, HEIs are required to invest in their brands and fulfill research-related requirements (like increased numbers of publications, citations, and collaborations) that are expected to put them higher up the ranking tables and build their international competitiveness. In other words, governance reforms around the world have now engaged HEIs in an "arms race of research and publication, fueled by financial incentives" (Zhang et al., 2016, p. 870) with the hope that they can be classified as world-class.

Indonesian HEIs provide a good example of this worldwide trend. Scopus data before 2014 shows that Indonesia's scientific productivity trailed behind neighboring countries like Malaysia, Thailand, and Singapore. To decrease this gap, Indonesia responded to the race for world-class status by implementing a series of policies that aimed to transform its scientific capacity and place its HEIs among high-ranking universities in the world. Among those policies was the 2014 declaration of 11 state universities in Indonesia as autonomous HEIs, each provided with a yearly budget allocation and special privileges in the way they are governed and financed. However, being awarded autonomy meant they had to be included in the QS World University Ranking (WUR) top 500 by 2024 (Ristekdikti, 2017; Sukoco et al., 2021).

Scopus data after 2014 reveals increasing publications for Indonesia. In 2017, to improve on its scientific imperative and leverage its entire workforce (i.e., including those HEIs that were not declared in 2014 as autonomous, hereafter referred to as non-autonomous HEIs), a new policy mandated all researchers "to publish at least three papers in nationally indexed journals or one in an internationally indexed journal in the last three years to earn professional incentives" (Sandy & Shen, 2018, p. 251). Another look at the Scopus data reveals that Indonesia's research publications in international journals skyrocketed after 2017. We therefore explore Indonesia's dramatic growth in scientific production through the following research questions:

1. What are the publication and scientific collaboration patterns of autonomous and non-autonomous HEIs in Indonesia?
2. In which academic fields do Indonesian researchers in autonomous and non-autonomous HEIs publish?
3. What are the publication patterns by different cohorts of Indonesian researchers in autonomous and non-autonomous HEIs?

Literature review

Competition driving higher education

HEIs around the world are thriving in a competitive higher education environment that is dominated by ranking regimes and their focus on scientific production. This phenomenon has created an obsession with increased productivity (Nabout et al., 2015)—a competition fetish (Naidoo, 2018)—that is assumed to increase capacity nationally and, internationally, to build a country's global competitiveness. Some of these competition-grounded mechanisms significantly driving the landscape of higher education come in the form of the institutionalized reliance on rankings to build world class universities coupled with the proliferation of excellence initiatives.

Under this circumstance, university rankings provide national governments with a "policy instrument to measure and monitor the performance of universities and to steer their higher education sectors towards a global standard" (Lo & Allen, 2023, p. 211). The latter is particularly evident in Asia where national governments and university leaders primarily use performance metrics provided by university rankings to inform decision-making and determine resource allocation (Lo & Allen, 2023), contrary to the Western usage of ranking metrics where they largely influence student college choice (Hazelkorn, 2015). In other words, university rankings within the Asian context are the driving force behind policies that create a highly competitive, performance-driven higher education environment where research outputs become more calculable and comparable. China's 985 Project, Malaysia's Education Blueprint, South Korea's Brain Korea 21, and world-class university initiatives in Japan, Singapore, and Taiwan are a few forms of higher education policies that rely on international university rankings as a benchmark not only for assessing performance but for building international reputation and signaling excellence. In other world regions, the United Kingdom, Germany, France, Italy, Spain, Russia, and Australia are some countries that have also launched excellence initiatives in the last two decades.

Aptly named, excellence initiatives push higher education systems to boost research performance through selection and a greater concentration of resources (Hazelkorn, 2015; Salmi, 2016). They have a well-documented positive impact on the volume of publications among funded universities, as in the case of South Korea (Shin, 2009), China (Zhang et al., 2013), Russia (Agasisti et al., 2018; Matveeva et al., 2021), and Germany (Civera et al., 2020). Along with this growth, co-authored publications and multiple affiliations of a single author increased simultaneously (Hottenrott et al., 2021; Matveeva et al., 2021), while spillover effects are observed among non-participants (i.e., those HEIs not selected to be part of an excellence initiative) in Germany (Esterhazy, 2018), Taiwan (Fu et al., 2020), Russia (Lovakov et al., 2021), and China (Zhang et al., 2013).

Scientific production tied to incentives

The competition created by higher education policy models such as excellence initiatives may be driving the growth in scientific production for HEIs, but at the individual level, researchers are directly pressured to keep the momentum of production. Such pressures are derived from policy reforms that are rooted in performative accountability (Oancea, 2008), which measures "performance against externally determined targets…and quantifiable outcomes" (Oancea, 2008, p. 167). Priority is given to the quantification of scientific output and serves as a metric for comparability (Tian & Lu, 2017). Excellence initiatives and policies that reward quantifiable outputs enable policymakers to determine the allocation of public funds based on scientific production. Researcher output can then be assessed, and their performance rewarded. In the Indonesian case, universities are predisposed not only to rewards but to penalties. Budget cuts are eventually imposed on universities that fail to meet the output requirements (Ngo & Meek, 2019), while salary deductions are imposed and supervisory responsibilities are withheld from individual researchers who fail to publish, creating greater impact even on their reputation (Sukoco et al., 2021).

Given simultaneous reward and penalty-motivated pressures created by ranking and incentive regimes, HEIs and individual researchers are left with no choice but to meet intensive demands for production. On the positive side, performance-based funding has translated to increased publication outputs and collaborations with other universities and research institutions (Bordons et al., 2015; De Filippo et al., 2016; Guskov et al., 2018; Matveeva et al., 2021). However, the focus on quantifiable outcomes may bring potential negative and unintended effects on scientific productivity and harm the practice of science (Qiu, 2010; Sandy & Shen, 2018). For instance, Adler and Harzing (2009) note that to meet the standards required to earn financial and promotional incentives, researchers change their focus from producing innovative research to simply producing publications that can add to their publication count. Alvesson and Sandberg (2013) provide evidence of this by observing a serious shortage of innovative research despite an increase in publications in management studies. Through computational modeling, Smaldino and McElreath (2016) also provide evidence that rewarding and incentivizing publication quantity encourages "the natural selection of poor methods" by researchers (p. 13). In this sense, researchers might be encouraged to shift towards the homogenization of knowledge production which discourages new and innovative research (Geuna & Martin, 2003; Gonzales & Núñez, 2021). Simply focusing on quantity rather than quality, an orientation to less innovative and more mainstream research and producing publishable results becomes the aim, potentially stifling innovation and diminishing creativity (Tijdink et al., 2013).

The inflation of publications reveals researchers' opportunistic responses to the pressures created by increased demands for scientific production. Publishing in a high-quality, peer-reviewed journal is a lengthy and time-consuming process, and researchers might resort to paying for expedited publications in low-quality journals, sometimes called predatory journals, to attain incentives or avert penalty (Al-Khatib, 2016; Chavarro et al., 2017; Lukić et al., 2014). Perlin et al. (2018) show this by applying econometric methods on publication data by Brazilian researchers between 2000 and 2015. They show that incentives for publications can help explain an exponentially increasing propensity to publish in predatory outlets. Demir (2018a, 2018b) adds support to such findings by identifying a big increase in the number of publications in predatory journals by Turkish researchers following the implementation of an incentive program in 2015. Chan (2019) summarized this potential unintended effect of the reliance on performance outputs in saying that Malaysian authors were more "motivated by rapid publication, less onerous review processes and not by the reputation of these journals" (p. 75).

The Indonesian context

Although there are several university rankings systems, the ARWU, QS WUR, THE, and CWTS Leiden ranking systems are the most popular (Olcay & Bulu, 2017) and are often widely used to drive policy reforms (Hazelkorn, 2015; Lee et al., 2020). From these, only the ARWU and CWTS Leiden ranking systems focus heavily on research quality and bibliometrics; the others focus less on research outputs and include other metrics such as reputational and employability surveys, internationalization metrics, and university-specific characteristics. Against such backdrop, national governments seeking to have globally high-ranking HEIs must decide on the ranking standard to adopt. The choice then becomes consequential as each ranking metric builds up to determine a university's reputation.

Such is the Indonesian case. Despite having a quite expansive higher education system, Indonesia's HEIs are still not highly placed in ranking systems and its scientific productivity still lags behind neighboring countries. To keep up with the competition, the government passed two important policies that leverage its academic community to increase scientific production. The first was the 2014 declaration of 11 state universities to become autonomous (Table 2) in the management of "academic and non-academic activities, including financial matters, more independently, transparently and in a more accountable way" (Sukoco et al., 2021, p. 564). The policy also required autonomous HEIs to create a work program to improve their rankings and be in the QS WUR top 500 by 2024. In fact, five of these 11 autonomous HEIs were expected to be included in the QS WUR top 500 in 2019, with the rest joining by 2024 (Ristekdikti, 2017; Sukoco et al., 2021). While the rationale behind their choice of ranking system is unclear, the 2014 policy was followed by the placement of three autonomous HEIs in the QS WUR top 500 in 2019 and five in 2023.

The second policy was a 2017 criterion applied on its entire scientific workforce to have at least three publications in nationally indexed journals or one publication in an internationally indexed journal within the previous 3 years so they can earn financial and promotional incentives (Sandy & Shen, 2018). This implementation of back-to-back policies that seems to convey building pressure to catch up with the global higher education competition allows the opportunity to reveal patterns in Indonesia's history of scientific publication, particularly its performance across fields, the quality of publications, and differences in individual productivity. We explore these through a bibliometric analysis of scientific production within the context of Indonesia's higher education system.

Methodology

Data collection

We used the Scopus database as our source because it has several advantages over other databases, such as author disambiguation that provides unique author and affiliation IDs, the latter providing information on the country and organization type (Hottenrott et al., 2021). To retrieve bibliometric data on all documents published with Indonesian affiliations from 1990 to 2020, we used Rose and Kitchin's (2019) pybliometrics module, which enables the search and retrieval of data on Scopus publications via a Python environment. An efficient alternative to downloading manual entries on Scopus, the package allows customizable queries on affiliations, documents, authors, abstracts, among other publication elements (Rose & Kitchin, 2019).

We first retrieved affiliations and then the documents published with these affiliations. We used "Indonesia" under the affiliation query. To ensure the accuracy of our list, we verified the country information and dropped any affiliation that was not from Indonesia, resulting in 2186 affiliations with information on the country, city, address, and unique Scopus ID. The next step was to use the affiliations' IDs to perform another search query and retrieve all documents that are published under these IDs.

Despite Scopus' disambiguation advantage, variations in institutional IDs which may refer to the same institution might still exist. We therefore standardized the institutional IDs by manually cleaning our data based on location and other relevant information. Our final dataset consists of 1707 higher education institutions, which were divided into (a) the 11 autonomous HEIs assigned by the Indonesian government and (b) the remaining universities as non-autonomous HEIs.

Since we are also interested in the types of co-authoring organizations in the publications we retrieved, we classified the affiliations into seven types: autonomous HEIs, non-autonomous HEIs, medical institutes, industry, research institutes, other domestic organizations, and foreign organizations. All but the last are affiliations within Indonesia; foreign organizations include universities and all other types of organizations whose country information is not Indonesia.

To identify the journal's academic field, we used Scopus' All Science Journal Classification (ASJC) codes which sort journals on three levels. On the first level, journals are classified into five general categories: (a) multidisciplinary, (b) social sciences, (c) physical sciences, (d) life sciences, and (e) health sciences. On the second level, they are classified into 27 more specific fields nested under these general five. On the third, most detailed level, they are classified into 334 fields. For example, a journal is classified under epidemiology on the third level, medicine on the second level, and health sciences on the first level. We draw this distinction in the nesting of ASJC fields because our analysis of publications by field only uses the first-level classification even though we determine the quality of a journal based on its performance on the third-level field.

To retrieve an indicator of the quality of a publication, we linked its year of publication and publishing journal's Scopus source ID to the journal's Scopus-generated CiteScore. The CiteScore captures the citations to the journal across 4 years including the year of publication, divided by the number of the same document types in Scopus published in the same 4 years. CiteScores are ranked, and journals are then divided into quartiles. This means that the CiteScore as an indicator of quality changes for each journal every year, which therefore affects the yearly quartile classification of the journal. As previously mentioned, CiteScores are generated based on a journal's performance in its third-level field, which means journals affiliated to multiple fields have one CiteScore per year for each field. For this study, we applied a generous classification and chose the best quartile among all fields tagged to a journal in a given year as an indicator of its quality in that year.

In Indonesia's case, some journals on Scopus do not have a quartile ranking; out of 9185 journals, 718 fall into this category. There are three possible reasons for this: 322 journals have publication concerns raised by Scopus regarding their review process, 128 journals are too new to have a CiteScore, and 268 journals were recently assigned CiteScores after being unclassified for a while. In our analysis, we use the same unclassified label for these

Table 1 Academic fields and sub-areas, 1990–2020

Academic field	Description	ASJC	Manually Coded
Multidisciplinary	Multidisciplinary	40	16
Social sciences	Arts and Humanities, Business, Management and Accounting, Decision Sciences, Economics, Econometrics and Finance, Psychology, Social Sciences	1879	197
Physical sciences	Chemical Engineering, Chemistry, Computer Science, Earth and Planetary Sciences, Energy, Engineering, Environmental Science, Materials Science, Mathematics, Physics and Astronomy	2910	248
Life sciences	Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology, Immunology and Microbiology, Neuroscience, Pharmacology, Toxicology and Pharmaceutics	1536	149
Health sciences	Medicine, Nursing, Veterinary Medicine, Dentistry, Health professions	2102	108
Total		8467	718

journals. Since Scopus does not provide an ASJC code for unclassified journals, we manually assigned them to the relevant field based on information on their websites. Table 1 shows the distribution of journals by field.

In addition to the scale of scientific production in Indonesia, we are also interested in individual-level changes in productivity before and after 2014, which marks the year when the first policy was introduced. For this, we gathered a list of all authors in the retrieved documents published by Indonesian affiliations from 1990 to 2020, a process that yielded 162,882 unique author IDs. To keep only new researchers that were primarily affiliated to Indonesian HEIs, we selected only authors who met the following criteria: (1) more than half of their publication records have Indonesian HEIs as affiliation, and (2) their first publication records are between 1990 and 2020. This selection gave us 94,182 new researchers within the study period. Table 2 presents the two main variables used in our empirical investigation: the total number of publications and the total number of new researchers from 1990 to 2020.

Analytical strategy

Indonesia's higher education system is rendered complex by the multiple authorities involved in its governance. Adding to the complexity are reform policies that change very quickly, thereby creating a severe challenge for policy evaluation. Our study aims to capture changes in the higher education landscape before and after 2014, when the first policy we examine was implemented. We use a descriptive analytical strategy for this purpose.

To ensure the consistency of our analysis, we use the metadata of each publication extracted from Scopus to generate an indicator of scientific production at a chosen unit level. We apply the whole count strategy—one count per publication per chosen unit—to calculate production at any of the following unit levels: group, institutional, and individual level. To illustrate this, consider a publication with three unique author IDs from three unique affiliation IDs where one is an autonomous HEI and the two being non-autonomous HEIs. At the group level, autonomous and non-autonomous HEIs get only one count

Table 2 Number of publications and new researchers, autonomous and non-autonomous HEIs, 1990–2020

No	Autonomy	Higher education institutions	Publications	New researchers
1	Autonomous	Universities Indonesia	9205	7276
2	Autonomous	Institut Teknologi Bandung	6113	3972
3	Autonomous	Universitas Gadjah Mada	7908	5433
4	Autonomous	Universitas Padjadiaran	3739	3183
5	Autonomous	Institut Pertanian Bogor	5451	3546
6	Autonomous	Universitas Airlangga	6350	5492
7	Autonomous	Universitas Diponegoro	3677	3034
8	Autonomous	Institute Teknologi Sepuluh Nopember	2896	2218
9	Autonomous	Universitas Brawijaya	4414	3622
10	Autonomous	Universitas Sebelas Maret	2216	2026
11	Autonomous	Universitas Hasanuddin	3631	3023
	Non-autonomous	1696 Higher Education Institutions	60,842	51,357
Total			116,442	94,182

Note: whole count at institutional level each, regardless of the number of autonomous or non-autonomous HEIs in the publication. At the institutional level, each affiliation ID gets one count. At the individual level, each author ID gets one count. This practice ensures that there is no production inflation, especially when scientific collaboration is investigated. We make note of the chosen unit level under each table and figure we present.

We first explore scientific production patterns at the institutional level before and after 2014 via the number of publications. To reveal more detailed changes, we divide results by the two groups of universities—autonomous and non-autonomous HEIs—to highlight their scientific production and collaboration patterns across journal quartiles from 1990 to 2020. Therefore, we investigate patterns of publication and collaboration by academic field at the group level. Finally, we examine the developments within the scientific workforce by comparing the publication patterns of two cohorts of new researchers at the individual level: those who made their first publications between 2011 and 2013 and those who did so between 2014 and 2016. We track 5 consecutive years of publication activity after the first publication year and apply an OLS regression model to test whether there are statistically significant differences between the two cohorts on publications across quartiles.

Empirical findings

Our findings first describe publication trends from 1990 to 2020 to historically capture scientific production surrounding the policy reform of 2014, the rewarding of autonomy on a select group of HEIs tasked with gaining placement in the QS WUR top 500, and of 2017, the requirement of increased domestic and international publications for promotion and additional incentives. Then, our empirical investigation presents three levels of analysis: scientific production at the institutional from 1990 to 2020, scientific collaboration patterns

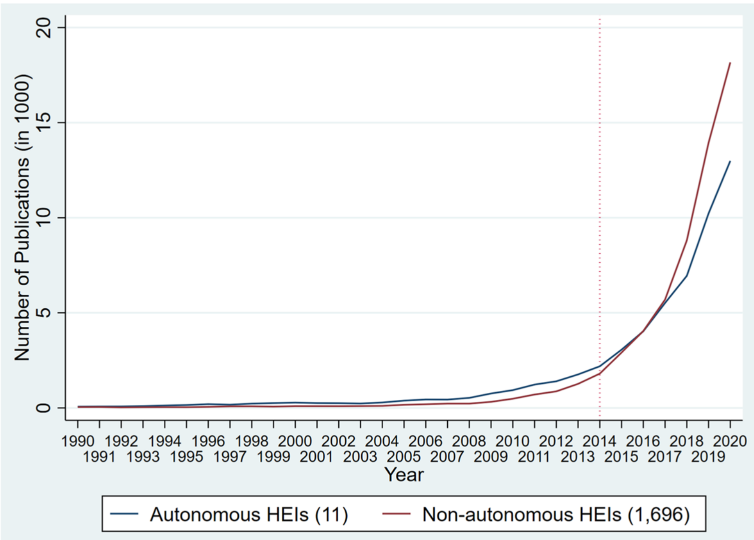

Fig. 1 Scientific production, autonomous and non-autonomous HEIs, 1990–2020. Note: whole count at institutional level

Table 3 National share of publications, autonomous and non-autonomous HEIs, 1990–2020

		Autonomous HEIs		Non-autonomous HEIs	
Year	Total publications	Count	Share (%)	Count	Share (%)
1990	111	68	61.26	43	38.74
1995	190	153	80.53	37	19.47
2000	375	280	74.67	95	25.33
2005	550	384	69.82	166	30.18
2010	1,418	935	65.94	483	34.06
2015	5,975	3,063	51.26	2,912	48.74
2020	31,163	12,992	41.69	18,171	58.31

Note: whole count at institutional level. Source: Authors' calculation on Scopus data

at the group level from 2014 to 2020, and new researchers' publication behavior at the individual level since 2011.

Patterns of scientific production and collaboration

To answer our first research question, we compute the number of publications by the two types of universities from 1990 to 2020. We provide in Fig. 1 and Table 3 the historical trend of scientific publications during this period.

Before 2010, the entire Indonesian higher education system only had marginal scientific production, a scenario that is evident in both groups of HEIs. In 1990, there were only 68 publications by autonomous HEIs and 43 publications by non-autonomous HEIs. Autonomous HEIs were the first group to raise their scientific production. After a decade, there were 280 publications produced by autonomous HEIs, while the publications by non-autonomous HEIs totaled 95. In the early 2000s, the scientific productivity of both groups remained relatively stable; however, publications by non-autonomous HEIs shrunk the difference between the two groups. By 2010, there were 935 publications produced by autonomous HEIs and 483 publications produced by non-autonomous HEIs. In two decades, production was 14 times more in autonomous HEIs and around 11 times more in non-autonomous HEIs.

Before the policy reform in 2014, both groups of HEIs showed initial growth in publications. Publications by autonomous HEIs increased more than threefold from 935 in 2010 to 3,063 in 2015. Publications by non-autonomous HEIs rose six-fold from 483 to 2,912 in the same period, almost catching up in raw publication numbers. Within this window of 5 years, we begin to see the growth rate of publications by non-autonomous HEIs surpassing that of the autonomous HEIs.

In 2020, publications by autonomous HEIs reached 12,992, increasing more than four times from 2015. More dramatic was the productivity rate among non-autonomous HEIs, which produced 18,171 publications, increasing more than six times in the same period. In 2015, publication numbers by autonomous and non-autonomous HEIs were very similar, but within-group growth rates indicate that publications by non-autonomous HEIs dramatically increased even though they did not necessarily have a pressing responsibility, from national policy in the form of rewards and penalties, to produce research. Since 2015,

Table 4 Collaboration patterns by journal quartile, 2014–2020

	Total	Q1	Q2	Q3	Q4	Unclassified
Autonomous HEIs						
Single	29,395 (100.0)	5363 (18.2)	5671 (19.3)	8595 (29.2)	5677 (19.3)	4089 (13.9)
Autonomous HEIs	2604 (100.0)	449 (17.2)	501 (19.2)	829 (31.8)	490 (18.8)	335 (12.9)
Non-autonomous HEIs	10,905 (100.0)	1274 (11.7)	2096 (19.2)	3566 (32.7)	2187 (20.1)	1782 (16.3)
Medical institute	1356 (100.0)	232 (17.1)	280 (20.6)	480 (35.4)	223 (16.4)	141 (10.4)
Industry	496 (100.0)	123 (24.8)	136 (27.4)	139 (28.0)	58 (11.7)	40 (8.1)
Research institute	2737 (100.0)	633 (23.1)	597 (21.8)	825 (30.1)	444 (16.2)	238 (8.7)
Other domestic org	1272 (100.0)	306 (24.1)	233 (18.3)	355 (27.9)	208 (16.4)	170 (13.4)
Foreign org	10,830 (100.0)	4625 (42.7)	2788 (25.7)	1940 (17.9)	926 (8.6)	551 (5.1)
Non-autonomous HEIs						
Single	27,188 (100.0)	3805 (14.0)	4594 (16.9)	7519 (27.7)	5468 (20.1)	5802 (21.3)
Autonomous HEIs	10,847 (100.0)	1270 (11.7)	2086 (19.2)	3545 (32.7)	2178 (20.1)	1768 (16.3)
Non-autonomous HEIs	8129 (100.0)	917 (11.3)	1380 (17.0)	2065 (25.4)	1466 (18.0)	2301 (28.3)
Medical institute	709 (100.0)	125 (17.6)	143 (20.2)	225 (31.7)	136 (19.2)	80 (11.3)
Industry	330 (100.0)	49 (14.8)	65 (19.7)	114 (34.5)	53 (16.1)	49 (14.8)
Research institute	1525 (100.0)	345 (22.6)	320 (21.0)	469 (30.8)	232 (15.2)	159 (10.4)
Other domestic org	899 (100.0)	174 (19.4)	172 (19.1)	262 (29.1)	132 (14.7)	159 (17.7)
Foreign org	10,277 (100.0)	3390 (33.0)	2509 (24.4)	2283 (22.2)	1082 (10.5)	1013 (9.9)

Note: whole count at group level; % in parentheses. Source: Authors' calculation on Scopus data

non-autonomous HEIs have surpassed autonomous HEIs as the driving force behind Indonesia's scientific production, and this divergence has continued to expand.

The dramatic change in scientific production in Indonesia between 2014 and 2020 raises several issues, among which we focus on the quality of the publications and the scientific collaboration patterns. From Table 4, we observe that cross-sector scientific collaboration is not common. Authors with a single-university affiliation accounted for 65.3% of all 44,964 publications produced by autonomous HEIs, followed by collaboration with authors in non-autonomous HEIs (24.2%) and with foreign organizations (24.0%). A similar scenario is observed in non-autonomous HEIs. Most publications are affiliated to a single university, accounting for 49.0% of the total 55,375 publications, followed by collaboration with autonomous HEIs (19.5%), and foreign organizations (18.5%).

Publications by autonomous HEIs, either single-university–affiliated or in collaboration with other organizations, are mostly in Q3 journals, except when these are co-authored with foreign organizations, 42.7% of which are published in Q1 journals. Meanwhile, publications by non-autonomous HEIs are similarly mostly in Q3 journals with around half of their collaborations with foreign organizations mostly published in Q1 and Q2 journals. However, a fifth of all publications by non-autonomous HEIs, which are authored by a single-university affiliation, and another fourth that are co-authored with other non-autonomous HEIs are published in journals that are unclassified by Scopus. It is noteworthy that

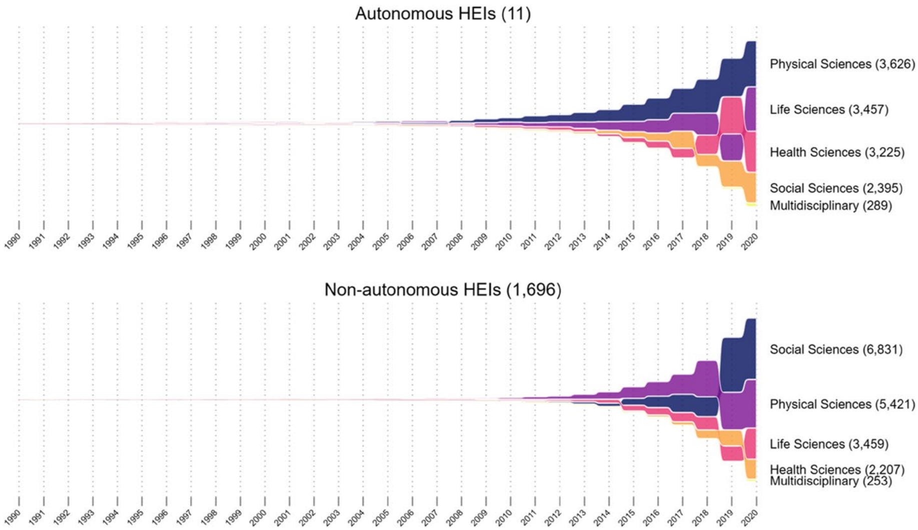

Fig. 2 Growth of publications by academic field, 1990–2020. Note: whole count at group level

18.05% of all publications produced by Indonesia's higher education system (i.e., autonomous and non-autonomous HEIs) are published in unclassified journals.

Publications by academic field

Our second research question focuses on the growth of scientific production by academic field and by type of university. Appendix 1 documents the number of publications by academic field and type of university. In Fig. 2, the position of an academic field on a given year shows its ranking. The area each individual color occupies reflects the total volume of publications per academic field.

For autonomous HEIs, while most academic fields experienced modest scientific growth with the exception of the multidisciplinary group, the physical sciences have been taking the lead. Since 2010, the number of publications in the physical sciences started to increase followed by the life sciences, which started to grow in 2014. Publications in the health sciences and the social sciences also started to increase almost at the same time around 2016, with the former eventually surpassing the latter to be the third biggest producing field by 2018. In 2020, although publications took off at different time points for the fields, all but the multidisciplinary group had about the same number of publications by 2020. There were 3626 publications in physical sciences, 3457 in life sciences, 3225 in health sciences, 2395 in social sciences, and only 289 in the multidisciplinary group.

In contrast, in non-autonomous HEIs, academic fields show different growth patterns. The physical sciences first took off in scientific production around 2012 when the number of publications totaled 1310 in 2015. Meanwhile, publications in the life sciences took off around 2014 and doubled from 2014 to 2017. The health sciences were last to take off in 2017. Publications in social sciences increased 3.5 times in the same period, a dramatic increase evidenced by its moving ahead of the physical sciences. In 2016, there were only

Table 5 Collaboration patterns by academic field, 2014–2020

	Total	Multidisciplinary	Social sciences	Physical sciences	Life sciences	Health sciences
Autonomous HEIs						
Single	29,395 (100.0)	536 (1.8)	5506 (18.7)	9691 (33.0)	7140 (24.3)	6522 (22.2)
Autonomous HEIs	2604 (100.0)	58 (2.2)	294 (11.3)	875 (33.6)	724 (27.8)	653 (25.1)
Non-autonomous HEIs	10,905 (100.0)	156 (1.4)	2150 (19.7)	3986 (36.3)	2734 (25.1)	1879 (17.2)
Medical institute	1356 (100.0)	31 (2.3)	75 (5.5)	79 (5.8)	318 (23.5)	853 (62.9)
Industry	496 (100.0)	12 (2.4)	66 (13.3)	204 (41.1)	154 (31.0)	60 (12.1)
Research institute	2737 (100.0)	79 (2.9)	202 (7.4)	1030 (37.6)	1071 (39.1)	355 (13.0)
Other domestic org	1272 (100.0)	44 (3.5)	208 (16.4)	349 (27.4)	367 (28.9)	304 (23.9)
Foreign org	10,830 (100.0)	403 (3.7)	1461 (13.5)	4544 (42.0)	2316 (21.4)	2106 (19.4)
Non-autonomous HEIs						
Single	27,188 (100.0)	335 (1.2)	10,099 (37.1)	10,148 (37.3)	4106 (15.1)	2500 (9.2)
Autonomous HEIs	10,847 (100.0)	155 (1.4)	2139 (19.7)	3967 (36.6)	2718 (25.1)	1868 (17.2)
Non-autonomous HEIs	8129 (100.0)	98 (1.2)	3359 (41.3)	2583 (31.8)	1323 (16.3)	766 (9.4)
Medical institute	709 (100.0)	12 (1.7)	26 (3.7)	46 (6.5)	168 (23.7)	457 (64.5)
Industry	330 (100.0)	6 (1.8)	78 (23.6)	136 (41.2)	90 (27.3)	20 (6.1)
Research institute	1525 (100.0)	46 (3.0)	141 (9.2)	624 (40.9)	548 (35.9)	166 (10.9)
Other domestic org	899 (100.0)	30 (3.3)	262 (29.1)	224 (24.9)	222 (24.7)	161 (17.9)
Foreign org	10,277 (100.0)	281 (2.7)	2383 (23.2)	4922 (47.9)	1663 (16.2)	1028 (10.0)

Note: whole count at group level; % in parentheses. Source: Authors' calculation on Scopus data

1281 social science publications. This number increased fivefold to 6831 in 2020. In the same period, the physical sciences showed a threefold increase. By 2020, social sciences was the biggest producing field among non-autonomous HEIs, followed by physical sciences, life sciences, health sciences, and the multidisciplinary group.

We further investigate scientific collaboration patterns by academic field that drive the increase in publications in recent years (Table 5). For autonomous HEIs, across all five academic fields, single-university–authored publications comprise the biggest share of publications. However, there are several variations across collaboration partners and academic fields. First, researchers in autonomous HEIs tend to collaborate more with foreign organizations and industry when publishing in the physical sciences. Expectedly, medical institutes are the biggest collaboration partner in the health sciences.

For non-autonomous HEIs, publications authored by a single-university affiliation also drive the volume of publications across all five academic fields. Like autonomous HEIs, non-autonomous HEIs largely collaborate with foreign organizations and industry for publications in the physical sciences. In contrast, the social sciences are a major area where they publish with a single-university affiliation or collaborate with other non-autonomous HEIs. As in the case of autonomous HEIs, collaborations with medical institutes drive publications by non-autonomous HEIs in health sciences.

We focus on publications authored by a single university or in collaboration with foreign organizations. Appendix 2 documents publications, specifically single-university–affiliated publications and those co-authored with foreign organizations, by academic field, journal quartile, and type of university. We illustrate these in Fig. 3. For single-university–affiliated publications produced by autonomous HEIs, authors largely publish in unclassified journals in social sciences, while life, health, and physical science publications are mostly in Q3 and Q4 journals.

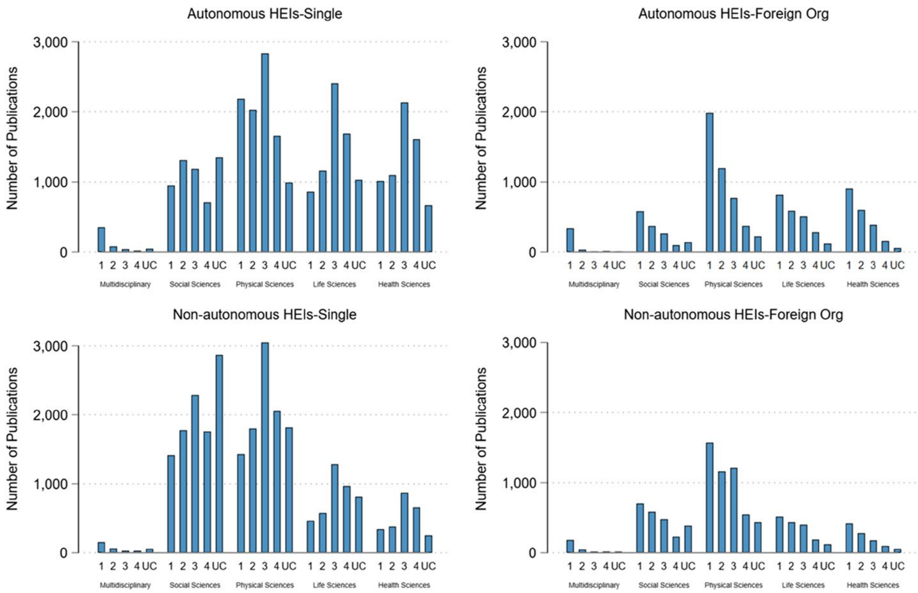

Fig. 3 Comparison across journal quartiles, academic fields, and collaboration partners, 2014–2020. Note: whole count at group level

In social sciences, non-autonomous HEIs have a substantial number of publications in unclassified journals. Physical science publications are mostly in Q3 journals. While health sciences have fewer publications in unclassified journals compared to other fields, the bulk of publications by non-autonomous HEIs remain in Q3 and Q4 journals.

We have previously shown that publications co-authored with foreign organizations enjoy higher journal quality publication, although more apparent among autonomous HEIs and consistent across all five academic fields. For both autonomous and non-autonomous HEIs, we also obverse smaller ratios of publications in unclassified journals, except in social sciences where publications co-authored with foreign organizations in unclassified journals outnumber those in Q4 journals.

Publications by research cohort

We qualify our definition of new researcher by identifying them by the year of their first publication. This way, a new researcher is counted only once in the period studied. Figure 4 shows the increase in researchers is very similar to the growth of scientific publications. Before 2010, there were only very few new researchers annually. In 2010, the whole system had 1,285 new researchers, 686 of which were affiliated with autonomous HEIs and 599 with non-autonomous HEIs. This changed in 2014, when 1,714 new researchers were in autonomous HEIs and 1,799 were in non-autonomous HEIs, marking the first time that the latter group recorded more new researchers compared to autonomous HEIs. By 2020, among 18,579 new researchers, 59.07% of which were in non-autonomous HEIs and 40.93% were in autonomous HEIs. Within one decade, the number of new researchers in 2020 increased 14.4 times since 2010 (Table 6).

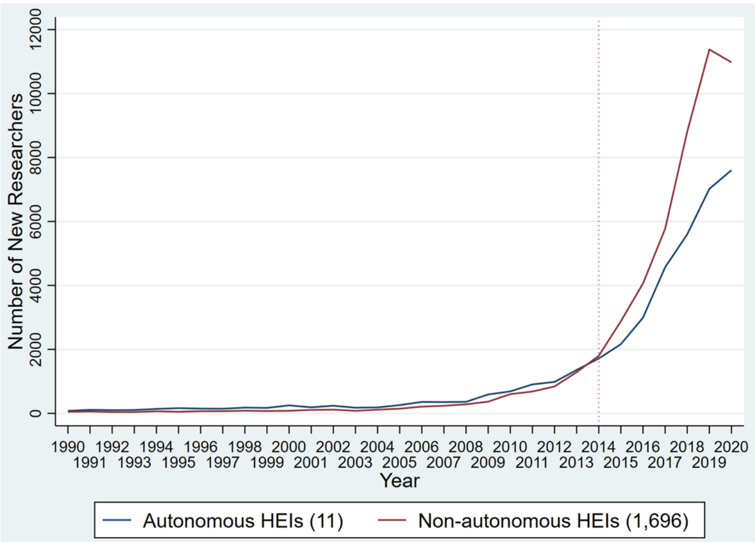

Fig. 4 Number of new researchers, autonomous and non-autonomous HEIs, 1990–2020. Note: whole count at institutional level

Table 6 National share of new researchers, autonomous and non-autonomous HEIs, 1990–2020

Year	New researchers	Autonomous HEIs		Non-autonomous HEIs	
		Count	%	Count	Share (%)
1990	126	78	61.90	48	38.10
1995	210	162	77.14	48	22.86
2000	329	249	75.68	80	24.32
2005	402	257	63.93	145	36.07
2010	1285	686	53.39	599	46.61
2015	5044	2163	42.88	2881	57.12
2020	18,579	7604	40.93	10,975	59.07

Note: whole count at institutional level. Source: Authors' calculation on Scopus data

Table 7 First publication by researcher cohort and journal quartile

First publication	2011–2013		2014–2016	
Journal tier	Autonomous HEIs	Non-autonomous HEIs	Autonomous HEIs	Non-autonomous HEIs
Q1	1212 (0.40)	833 (0.36)	2479 (0.37)	1874 (0.23)
Q2	1228 (0.40)	686 (0.30)	3528 (0.52)	3166 (0.39)
Q3	2014 (0.66)	1358 (0.59)	7075 (1.05)	6872 (0.84)
Q4	1935 (0.36)	1266 (0.55)	5559 (0.82)	6441 (0.79)
Unclassified	1950 (0.64)	1482 (0.64)	3453 (0.51)	5301 (0.65)
Total	8339 (2.73)	5625 (2.43)	22,094 (3.27)	23,654 (2.91)
No. of researchers	3058	2316	6749	8136

Note: whole count at individual level; mean in parentheses. Source: Authors' calculation on Scopus data

Our third research question focuses on individual researchers' publications and compares publication patterns between two cohorts of researchers. Researchers whose first publication year was during 2011 to 2013 were assigned to one group while those who first published during 2014 to 2016 were assigned to a second group. We then tracked each researcher's publications for 5 consecutive years. For example, if a researcher first published in 2011, then we traced their publications until 2015.

Table 7 provides descriptive statistics on the number of researchers in autonomous and non-autonomous HEIs. From 2011 to 2013, there were fewer new researchers in non-autonomous HEIs than in autonomous HEIs. This was reversed by the second cohort, from 2014 to 2016. For both cohorts and both autonomous and non-autonomous HEIs, average production per researcher remains within the range 2.4 to 3.3 publications. Highest publication-per-researcher averages are observed in Q3 publications for both cohorts in autonomous HEIs and in unclassified and Q3 publications for the first and second cohorts in non-autonomous HEIs, respectively.

Table 8 presents findings from our OLS computation to compare publication patterns between the two cohorts in autonomous and non-autonomous HEIs. Using the

Table 8 Publication patterns by researcher cohort and journal quartile

DV: Publication	Q1		Q2		Q3	
	Autonomous HEIs	Non-autonomous HEIs	Autonomous HEIs	Non-autonomous HEIs	Autonomous HEIs	Non-autonomous HEIs
2011–2013						
2014–2016	−0.0290	−0.129***	0.121***	0.0929***	0.390***	0.258***
	(−1.31)	(−6.54)	(5.20)	(4.46)	(9.47)	(7.67)
Constant	0.396***	0.360***	0.402***	0.296***	0.659***	0.586***
	(21.54)	(20.61)	(20.77)	(16.13)	(19.30)	(19.74)
N	9807	10,452	9807	10,452	9807	10,452
DV: Publication	Q4		Unclassified		Total	
	Autonomous HEIs	Non-autonomous HEIs	Autonomous HEIs	Non-autonomous HEIs	Autonomous HEIs	Non-autonomous HEIs
2011–2013						
2014–2016	0.191***	0.245***	−0.126***	0.0117	0.547***	0.479***
	(5.93)	(7.73)	(−4.16)	(0.33)	(5.84)	(5.61)
Constant	0.633***	0.547***	0.638***	0.640***	2.727***	2.429***
	(23.68)	(19.54)	(25.35)	(20.75)	(35.11)	(32.30)
N	9807	10,452	9807	10,452	9807	10,452

t statistics in parentheses

*$p < 0.05$; **$p < 0.01$; ***$p < 0.00$

2011 to 2013 cohort as our reference group, we calculated coefficients by journal quartile to assess differences in production quality. In general, we see greater productivity for new researchers in the second cohort, right after the 2014 policy, in both autonomous and non-autonomous HEIs. However, the difference is skewed towards publications in journals of lower quality.

Considering totals, the second cohort from both groups of HEIs all produced more publications than the first cohort: 0.55 more publications in autonomous HEIs and 0.48 more publications in non-autonomous HEIs. However, investigating unit changes by quartile reveals that this increase is largely driven by Q3 and Q4 publications. The second cohort generally produced more publications than the first cohort in all quartiles but Q1. In non-autonomous HEIs, the second cohort produced fewer publications in Q1 journals than the first cohort who first published before the 2014 policy. In autonomous HEIs, the second cohort published less in unclassified journals than the first cohort.

Limitations

We present two limitations to our study. Although Rose and Kitchin's (2019) pybliometrics module and Scopus provide access to quality bibliometric data with the relevant standardized IDs, we acknowledge that inconsistencies in institutional IDs may still exist. Publications in Indonesia were not a common practice before the 2014 and 2017 policies; therefore, the way an affiliation is identified may not be standard. Although we standardize the institutional IDs by manually cleaning our data based on location and other relevant information, mistakes on the assignment may have occurred. The impact of this limitation at the institutional level computation is an issue; however, it becomes minor at the group level and does not affect our results primarily because the 11 autonomous HEIs are relatively standard, and the inconsistency was mostly seen in the 1696 non-autonomous HEIs. This issue may also occur in the individual level data; however, given the limited availability of information to identify the authors manually aside from their author IDs, we could only rely on Scopus' systematic identification.

Next, our analysis does not provide means to establish statistical comparability between the performance of autonomous and non-autonomous HEIs. However, throughout our analysis, we draw a distinction between their outputs to present a more nuanced differentiation before the 2014 reform when there was no grouping, following it, and through the 2017 reform, which in contrast took the system as a whole. The sample sizes differ significantly and annually; our analysis pools publications by autonomous HEIs from 1990 to 2020 together and publications by non-autonomous HEIs in the same period together, which does not allow attributing production to the growing number of universities per year. Establishing statistical comparability between the two to assess group superiority in performance before and after the policies constitutes an opportunity for further research. In this study, we take the perspective that indicators in terms of raw publication count and number of new researchers was around the same level for both groups by the time autonomous HEIs were selected in 2014 because we are primarily interested in the historical perspectives for each type of university (i.e., the progress of production through the enactment of the policies) rather than determining which group performed better.

Conclusion and policy implications

We investigate Indonesia's scientific production from 1990 to 2020. Patterns we observe before and after a series of higher education policies aimed at stimulating and incentivizing research production include dramatic changes in its research landscape. Rapid growth in science over the past decade signals dedication to research of the entire higher education system and the vision of the policies since 2014. However, the observed growth highlights potential areas for improvement in Indonesia's scientific production. Our analysis presents several important findings.

Like in other countries, Indonesia's pursuit for internationally high-ranking HEIs through excellence initiatives and reforms that incentivized scientific production proved fruitful in terms of increasing the volume of publications, albeit with some concerns. After the 2014 policy, stimulating competition for resources and awarding autonomy seemingly paid off with increased publications in autonomous HEIs (see Fig. 1), yet pervasive effects are also noted as expressed through the growth of lower quality publications (see Table 4). It appears that the intended effect of mandating publications and awarding autonomy and special privileges to push HEIs to global university rankings comes with more complexities than initially envisioned. We also see indications of potential spillover effects among non-autonomous HEIs who, even without a similar policy-mandated obligation as autonomous HEIs to multiply production, showed dramatic growth in scientific production after 2014 with similar lower quality. Despite the lower quality of the output, spillover effects on non-participants have been concluded by other studies of excellence initiatives (Esterhazy, 2018; Fu et al., 2020; Lovakov et al., 2021; Zhang et al., 2013), which creates the opportunity for future studies to investigate how much of the production by non-autonomous HEIs was motivated by policies enacted on autonomous HEIs.

Our analysis also shows varying collaboration patterns and differential impacts on the quality of publications after the implementation of both policies. For autonomous HEIs, the volume of publications authored with a single-university affiliation is as much as those co-authored with different affiliations (see Table 4). Collaboration partners were diverse, although only collaborations with foreign organizations were generally published in top quality journals. Our findings are similar to Matveeva et al. (2021) who note that publications authored by multiple affiliations are more likely to be published in higher-quality journals, yet our results show that international collaborations increase this likelihood over domestic collaborations.

For non-autonomous HEIs, quite unique collaboration patterns and differential impacts on the quality of the publications are noted. While the non-autonomous HEIs increased their publication count almost parallel to that of the autonomous HEIs (see Fig. 1), many of the publications were authored by a single affiliation while the vast majority of collaborations with other non-autonomous HEIs remain in unclassified journals, and only foreign collaborations are associated with greater publication quality. Non-autonomous HEIs may not be the direct targets of the 2014 reform, but they may have adopted their own strategies to compete for resources. Coupled with the 2017 policy which demanded publications from all researchers, non-autonomous HEIs also responded to the mandates by ramping up their scientific productivity despite the wide-ranging quality.

We also note that after the implementation of both policies, autonomous HEIs published more in the physical sciences academic field while non-autonomous HEIs published more in social sciences. Perhaps the funding mechanisms used to finance these HEIs may be behind these publication patterns, or the academic orientation of each individual researcher may have driven this growth pattern, both assumptions of which constitute an opportunity for further investigation. Single-university–affiliated publications also remain the norm across all academic fields, with a large portion published in lower-quality and unclassified journals (see Table 5; Fig. 3). Similar to previous findings by Matveeva et al. (2021), collaborations drive publication in top quartiles, especially in physical sciences. However, the magnitude of this trend is smaller among non-autonomous HEIs particularly in physical and social sciences.

New researchers after 2014 showed different publication behaviors than their senior colleagues. They have increased scientific productivity, but publications from new researchers in non-autonomous HEIs largely remain in unclassified journals. New researchers in autonomous HEIs mainly publish in journals with moderate quality. In this case, the pursuit for publications in journals of moderate to lower quality might be attributed to the demand for quick publications. As suggested by previous studies (see Butler, 2003; Civera et al., 2020; Chan, 2019), the inflation of lower-quality publications is indicative of a response to regulatory pressures and performative evaluation approaches systematized by recent higher education policies aimed only at the race to place universities in global rankings.

Altogether, our results indicate that researchers in Indonesia responded to the policies by focusing on scientific output maximization over its quality as has been observed in Australia (Butler, 2003), Germany (Civera et al., 2020), and Malaysia (Chan, 2019). In Indonesia's case, the policies incentivized ranking visibility and publication counts, which likely motivated scientific production but with lower quality because it is generally "cheaper, easier, and faster to produce" (Matveeva et al., 2021, p. 10). Moreover, the simplistic and incentive-penalty nature of both policies likely signaled to Indonesian researchers that in such a highly competitive environment the one that "sells the most" is rewarded more than the one that "sells the most valuable" (Civera et al., 2020, p. 11). Such publication behaviors may suffice in the short term for ranking systems that value publication numbers, likely pushing universities into the top spots within global rankings, but without sustained research quality, the expected ranking visibility may not be sustainable in the long-term.

The policy implications of our findings are threefold. First, Indonesia's case calls for a balance in quantity and quality of scientific production. The 2014 and 2017 reforms, like the ubiquitous excellence initiative and other higher education reforms operating on selection and stratification, increased publications and welcomed more researchers but skewed production towards lower quality journals. As we present, during 2014 to 2020, 18.05% of the publications produced by Indonesian researchers are published in unclassified journals that are either too newly formed and still waiting to be ranked or deemed to conduct questionable review practices. Policymakers should keep in mind that simply focusing on publication output as "a key indicator of successful participation" in these policies (Matveeva et al., 2021, p. 3) does not suffice; footing in terms of quality is also required as seen in Taiwan (Fu et al., 2020), Norway (Schneider, 2009), and Finland (Mathies et al., 2020) where quality criteria for research publications are in place. We recognize that Indonesia has made advances in scientific production, but more might have been achieved had the policies also aimed at maximizing the value and quality of the scientific production. In line with mandates on publication quantity, reforms can be more comprehensive by introducing criteria that differentiate between quality segments, for example, incentivizing publications in Q1 or Q2 journals over publications in lower quality journals or incentivizing publications that are co-authored with foreign organizations, which are found to improve the quality of research (Abramo et al., 2014) and increase the visibility of HEIs (Sooryamoorthy, 2009).

Second, we find a bulk of output in Q3 and Q4 journals for the second cohort of new researchers in both autonomous and non-autonomous HEIs (see Tables 7 and 8), but which nevertheless shows increases in production. Indonesia has a large scientific workforce that, as our findings show, can produce despite the high-pressure research environment. Publishing in journals of lower quality could only be an indication that the current policies, explicit as they are in their mandate to publish specific numbers of papers in both domestic and international journals, do not provide avenues for researchers to be bolder in their research pursuit since they are already faced with pressures to produce quick results. Policymakers should keep in mind that high-quality research not only takes time to produce and publish but also requires sound financial investments and the reorganization of the higher education system (Matveeva et al., 2021). In Indonesia's case, policy streams that build a robust research infrastructure and motivate greater collaboration and intra-system mobility are yet to be integrated, mechanisms that have been documented to stimulate researcher impact and productivity (Fu et al., 2023; Sugimoto et al., 2017). We reiterate the necessity for diversified avenues for pursuing research for the entire academic workforce not only to increase scientific production but also to guarantee its quality.

Finally, our findings underscore the complex nature of excellence initiatives and policy reforms that seek to push universities into attaining world-class status. The institutionalization of ranking regimes and the accompanying systemic pressure on scientific production makes Indonesia only one of many higher education systems that have heavily relied on selection mechanisms to increase production and international competitiveness. Indonesia's approach to building world-class universities may have been ambitious, yet shortsighted. Salmi (2016) points out three complementary sets of factors needed to create world-class universities: (a) a high concentration of talents, (b) abundant resources, and (c) favorable governance. In Indonesia's case, although there are many new researchers joining the scientific production activity, a culture of excellence is lacking, which is required to craft a cluster of talents that can produce leading-edge, quality research. The Indonesian higher education system also continuously faces several issues like the persistent lack of public funding, a lack of research vision because teaching remains the priority and source of income for many universities, the need to master English at least to publish internationally, and, even after the 2014 reform, the highly questionable autonomy awarded to universities which includes budget cuts for failing to meet requirements (Ngo & Meek, 2019). Given this context, instead of only focusing on the performance of the university for ranking purposes, Indonesian policymakers should conduct higher education reforms that reflect a holistic perspective. For example, granting institutional autonomy, ensuring sufficient financial resources, and introducing appropriate accountability and governance systems, which have been seen as determinants of world-class status (Salmi, 2016), should all be appropriately addressed.

Our study shows Indonesia's pursuit for excellence as it leverages the magnitude of its scientific community to improve scientific production. The first reform selected a small number of its universities to place in global university rankings, while the next reform mobilized the entire scientific workforce to multiply production with contempt for quality. The next step might be to unpack its potential as a science system by reconsidering simplistic and penalty-motivated policies around rankings and incentives.

Appendix 1 Number of publications by academic field, autonomous and non-autonomous HEIs, 1990–2020

Year	Multidisci-plinary	Social Sciences	Physical Sciences	Life Sciences	Health Sciences
Autonomous HEIs (11)					
1990	0	4	16	14	34
1991	0	14	17	15	31
1992	0	12	16	19	33
1993	0	11	27	25	34
1994	0	10	35	29	51
1995	0	9	28	36	80
1996	3	16	54	61	65
1997	1	9	52	57	53
1998	1	7	72	55	91
1999	1	19	77	68	91
2000	0	14	85	83	98
2001	2	16	100	61	77
2002	1	31	65	71	82
2003	1	16	75	58	82
2004	2	27	100	79	79
2005	2	32	131	105	114
2006	12	41	134	135	121
2007	9	35	137	143	115
2008	8	36	220	124	141
2009	16	53	305	205	178
2010	23	106	346	287	173
2011	73	123	535	317	180
2012	65	126	576	376	256
2013	87	153	754	498	269
2014	64	272	935	674	244
2015	44	467	1,357	801	394
2016	90	643	1,712	1,035	552
2017	73	1,353	1,952	1,390	751
2018	86	978	2,659	1,703	1,518
2019	146	2,058	3,013	2,110	2,898
2020	289	2,395	3,626	3,457	3,225
Non-autonomous HEIs (1696)					
1990	0	2	9	11	21
1991	0	1	7	7	31
1992	0	3	9	9	5
1993	0	4	8	14	9
1994	0	7	9	15	9
1995	0	4	4	12	17
1996	0	3	19	28	5
1997	0	6	28	38	12

Year	Multidisciplinary	Social Sciences	Physical Sciences	Life Sciences	Health Sciences
1998	0	8	28	29	22
1999	1	4	15	32	18
2000	1	5	32	43	14
2001	0	11	37	29	17
2002	0	11	34	26	19
2003	1	16	54	16	12
2004	2	16	47	27	15
2005	1	21	74	49	21
2006	1	39	76	58	20
2007	6	31	93	66	31
2008	3	38	76	77	33
2009	10	44	122	101	43
2010	15	68	191	154	55
2011	50	118	323	157	56
2012	38	159	395	206	73
2013	62	253	596	276	78
2014	52	360	861	433	98
2015	46	764	1,310	633	159
2016	104	1,281	1,614	817	229
2017	54	2,039	2,225	1,028	351
2018	72	2,217	4,063	1,501	955
2019	102	6,128	4,214	1,732	1,762
2020	253	6,831	5,421	3,459	2,207

Note: whole count at group level

Appendix 2 Scientific collaboration patterns by academic field and journal quartile, autonomous and non-autonomous HEIs, 2014–2020

Autonomous HEIs (11)						Non-autonomous HEIs (1,696)					
Academic field	Quartile	(1)		(2)		Academic field	Quartile	(1)		(2)	
Multidisciplinary	1	352	65.7%	338	83.9%	Multidisciplinary	1	155	46.3%	184	65.5%
Multidisciplinary	2	79	14.7%	32	7.9%	Multidisciplinary	2	63	18.8%	48	17.1%
Multidisciplinary	3	40	7.5%	11	2.7%	Multidisciplinary	3	30	9.0%	16	5.7%
Multidisciplinary	4	19	3.5%	14	3.5%	Multidisciplinary	4	30	9.0%	17	6.0%
Multidisciplinary	U.C	46	8.6%	8	2.0%	Multidisciplinary	U.C	57	17.0%	16	5.7%

Autonomous HEIs (11)						Non-autonomous HEIs (1,696)					
Academic field	Quartile	(1)		(2)		Academic field	Quartile	(1)		(2)	
Social Sciences	1	951	17.3%	583	39.9%	Social Sciences	1	1414	14.0%	702	29.5%
Social Sciences	2	1309	23.8%	371	25.4%	Social Sciences	2	1776	17.6%	586	24.6%
Social Sciences	3	1185	21.5%	266	18.2%	Social Sciences	3	2285	22.6%	480	20.1%
Social Sciences	4	709	12.9%	98	6.7%	Social Sciences	4	1759	17.4%	230	9.7%
Social Sciences	U.C	1352	24.6%	143	9.8%	Social Sciences	U.C	2865	28.4%	385	16.2%
Physical Sciences	1	2187	22.6%	1984	43.7%	Physical Sciences	1	1430	14.1%	1570	31.9%
Physical Sciences	2	2026	20.9%	1194	26.3%	Physical Sciences	2	1800	17.7%	1160	23.6%
Physical Sciences	3	2831	29.2%	770	16.9%	Physical Sciences	3	3048	30.0%	1210	24.6%
Physical Sciences	4	1655	17.1%	372	8.2%	Physical Sciences	4	2053	20.2%	547	11.1%
Physical Sciences	U.C	992	10.2%	224	4.9%	Physical Sciences	U.C	1817	17.9%	435	8.8%
Life Sciences	1	859	12.0%	817	35.3%	Life Sciences	1	465	11.3%	517	31.1%
Life Sciences	2	1160	16.2%	590	25.5%	Life Sciences	2	577	14.1%	435	26.2%
Life Sciences	3	2404	33.7%	506	21.8%	Life Sciences	3	1285	31.3%	399	24.0%
Life Sciences	4	1686	23.6%	283	12.2%	Life Sciences	4	968	23.6%	190	11.4%
Life Sciences	U.C	1031	14.4%	120	5.2%	Life Sciences	U.C	811	19.8%	122	7.3%
Health Sciences	1	1014	15.5%	903	42.9%	Health Sciences	1	341	13.6%	417	40.6%
Health Sciences	2	1097	16.8%	601	28.5%	Health Sciences	2	378	15.1%	280	27.2%
Health Sciences	3	2135	32.7%	387	18.4%	Health Sciences	3	871	34.8%	178	17.3%
Health Sciences	4	1608	24.7%	159	7.5%	Health Sciences	4	658	26.3%	98	9.5%
Health Sciences	U.C	668	10.2%	56	2.7%	Health Sciences	U.C	252	10.1%	55	5.4%

Note: (1) single-university affiliation; (2) collaboration with foreign organization

U.C. unclassified; whole count at group level

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Data Availability Data available on request from the authors.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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